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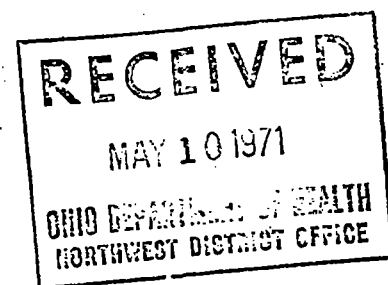
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REPORT OF INVESTIGATION  
GROUND-WATER SITE SURVEY  
2020 MANHATTAN BOULEVARD  
TOLEDO, OHIO



Purpose

During the month of August, 1968, field and laboratory studies were conducted at 2020 Manhattan Boulevard to determine the existing ground-water conditions. The purpose of these studies was to determine to what extent pollution of ground water at this site would affect other waters in the area, either above or below the ground.

It is proposed that this site be used as a test facility for mechanized burial of solid waste and possibly sewage sludge. Maximum burial will be nine feet beneath the ground surface which in many cases will also be below the water table. Introduction of waste material below the level of the water table will presumably cause pollution of the immediate ground water. This study determined the direction and rate of ground-water movement which are prime considerations in the dispersal of any pollutant. From this, conclusions are drawn on the potential hazard of the proposed waste disposal facility.

General Setting

The site at 2020 Manhattan Boulevard is a broad lowland of some

20 acres. Landfill operations at the north and southeast ends of the lowland have made significant headway in raising the general level of the land as much as 15 feet. Lowland, still not filled, is occupied by a pond which is drained to by a City of Toledo storm sewer. Before dumping began, the original level of the surrounding land was 16 to 18 feet above the pond level. Figure 1 is a plan view of the site at the time of the surveys.

### Geology

The area is underlain by a thick section (100 feet) of unconsolidated deposits related in origin to the Pleistocene glaciers. The deposits are predominately a gritty, and sometimes bouldery, silty clay loam (U.S. Department of Agriculture Soil Classification) termed till. This material was laid down directly by the glaciers as they advanced and retreated over the area. While heterogeneous in texture, the till is homogeneous in bulk composition, and should possess uniform hydrologic characteristics throughout its entire thickness.

Near the surface, the till has been reworked by weathering, mass movement, and erosion. As a result the texture is more silty and the material is less compacted.

Beneath the pond, and also in those areas the pond once occupied, the sediments at the surface consist of alluvium washed into the pond from the surrounding uplands. These sediments are rich in organic material and are classified as muck. Their thickness is approximately 6 feet.

Covering the glacial deposits is fill varying in thickness from

0 to about 15 feet. The fill is predominately demolition scrap, brick, wood, etc and industrial waste. It is heterogeneous in composition, and although compacted by machinery still contains numerous voids.

At depths of 100 feet the unconsolidated till is underlain by limestone which is persistent throughout Lucas County. The limestone contains many openings such as joints, solution cavities, and bedding planes. Due to these openings, water passes relatively freely through the rock. Because of this, the limestone is used extensively throughout the area as a source of water supply. It is estimated that approximately 10 million gallons per day is pumped from the limestone in the Toledo area.

To determine the geologic and hydrologic conditions at the site, borings were made at three locations (refer to figure 1) and samples of the deposits collected. Appendix A gives the lithologic logs of the borings, and appendix B the results of laboratory tests performed on undisturbed samples.

#### Ground-Water Hydrology

Before discussing the occurrence of ground water at the site, some general explanation of ground water behavior and definitions are in order.

Beneath the ground surface two major zones are distinguished on the basis of water content: the unsaturated and saturated zones. These are separated by the water table marking the upper-most extension of the zone of saturation. All water in the zone of saturation is termed groundwater to distinguish it from water in the unsaturated zone gener-

ally referred to as soil moisture. Surface water refers to all water at or on the ground surface and includes lakes, rivers, and ponds. These are necessarily artificial distinctions as there is direct transfer of soil moisture to ground water and to surface water and even the reverse.

The driving mechanism behind ground-water movement is gravity. At every point within the saturated zone, ground water possesses gravity potential. Movement will be initiated when the potential at one point is greater than at another with the direction of movement from high potential points to low potential points. Ground-water movement has been extensively investigated and found to obey Darcy's Law:

$$Q = PIA$$

where,

- Q = the rate of discharge,
- P = the permeability of the transmitting medium,
- I = the hydraulic gradient, or the potential loss divided by the distance of travel,
- A = the cross-sectional area through which flow occurs.

Ground-water conditions at the site are graphically shown in figure 2. The position of the water table is determined from static water levels in the boring holes. At the soil-fill interface there is a dislocation of the water table. This dislocation is due to changes in the hydraulic conductivity of the two materials resulting in lower gradients, or water table slopes in the fill.

In general, the water table slopes to the pond and is connected with the level of water in the pond. Where fill has been added, the water table has been displaced slightly upward but still retains its slope to the pond. The average horizontal gradient of the water table to the pond is 0.007 foot/foot.

As stated previously, the geologic properties of the glacial deposits are relatively uniform indicating that the hydrologic characteristics would also be uniform. This is confirmed by the laboratory tests. Porosity values range from 25 to 32 percent; moisture contents are 10.1 to 16.1 percent; and the coefficient of permeability is within the narrow limits of  $4.7 \times 10^{-1}$  to  $1.9 \times 10^{-1}$  gallons per day per square foot (gpd/ft<sup>2</sup>).

It should be pointed out that the difference between the porosity and moisture content values does not mean that the samples were unsaturated. These are apparent differences related to the method of reporting, i.e., moisture content in percent by weight and porosity in percent by volume. Conversion of moisture content into percent by volume gives close agreement with porosity. Thus, the samples are saturated as indicated by their position below the water table.

In addition to the horizontal gradient of 0.007 foot/foot, there is a vertical gradient through the till. From previous information collected on the hydrology of Lucas County, it can be shown that water levels in underlying limestone are approximately 30 feet below the level of the water table at the Manhattan Boulevard site. Thus the fluid potential in the limestone is significantly below the water table and water in the till will be induced to move down and into the limestone. The vertical hydraulic gradient is 0.30 foot/foot, or approximately 40 times greater than the horizontal gradient. In figure 2, the presence of the larger vertical gradient is denoted by arrows showing the pre-dominant path of water movement as vertically down.

Because of the strong vertical gradient, it can be seen from

figure 2 that there exists little chance of ground water within the glacial till discharging to the pond. In fact, pond water is leaking to the underlying deposits.

No flow lines have been drawn within the saturated fill. The fill material has unknown hydraulic properties and movement within the fill will be greatly controlled by the numerous interconnecting voids. Movement within the fill is definitely to the pond as the underlying deposits act as a relatively impermeable barrier. The rate of discharge will be small as the hydraulic gradient in the fill is less than 0.007 foot/foot.

All of the ground water within the glacial drift must eventually discharge to the underlying limestone bedrock. Thus, the possibility of pollution to the bedrock must be considered as the limestone represents a productive aquifer used locally for water supply.

Darcy's Law may be used to calculate the velocity and quantity of ground water movement through the till to the limestone. Using a value of  $3.3 \times 10^{-1}$  gpd/ft<sup>2</sup> as the average permeability of the till, the velocity of water movement through the till is 0.013 foot/day. At that rate water at the water table will require about 21 years to reach the limestone. The quantity of ground water discharged through the till amounts to 4,300 gpd/acre of land.

Because of the exceedingly slow rate of movement, it seems doubtful that pollution of the limestone aquifer will occur. During the time of travel, changes in the water quality will occur which will tend to purify the water. These changes include filtering of bacteria and sorption of chemical ions. Given the 20 years during which these reactions

can proceed, there is little likelihood of polluted water reaching the limestone.

#### Conclusions and Recommendations

The introduction of polluted material to ground water at the Manhattan Boulevard site presents minimal hazards to other waters in the immediate vicinity. This applies only if precautions are taken to not allow any polluted material to be buried within the fill.

Although the hydraulic characteristics of the fill are unknown, the nature of the material suggests that it is more permeable than the underlying glacial deposits. This suggestion is substantiated by a lower hydraulic gradient within the fill than in the glacial till, and by the water table discontinuity at the soil-fill interface. Pollutants within either the saturated or unsaturated fill will migrate laterally and enter the pond causing an undesirable situation for a long period of time.

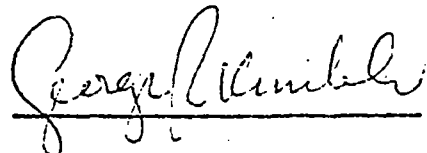
Burial of polluted material in the glacial deposits will restrict lateral seepage. Within both the saturated and unsaturated zones of the glacial deposits, the predominate direction of water movement is vertically down. This direction of movement precludes contamination of the pond even if the polluted material were buried beneath the pond itself.

As a precaution to inhibit lateral movement it is recommended that burial trenches be oriented normal to the direction of the horizontal hydraulic gradient. At the Manhattan site, this means that trenches run approximately east-west or parallel to the ground contour.

Vertical movement of pollutants are not seen to cause any hazard to the limestone aquifer buried beneath the glacial deposits. Movement through the deposits is extremely slow requiring some 20 years for water at the water table to seep into the limestone. During that period the water will be naturally purified by filtration and sorption.

While the conditions described represent those of August, 1968, no significant changes are anticipated either because of natural events such as wetter or dryer years, or because of man-made changes.

Respectfully submitted,

A handwritten signature in cursive script, reading "George R. Kunkle", written over a horizontal line.

George R. Kunkle